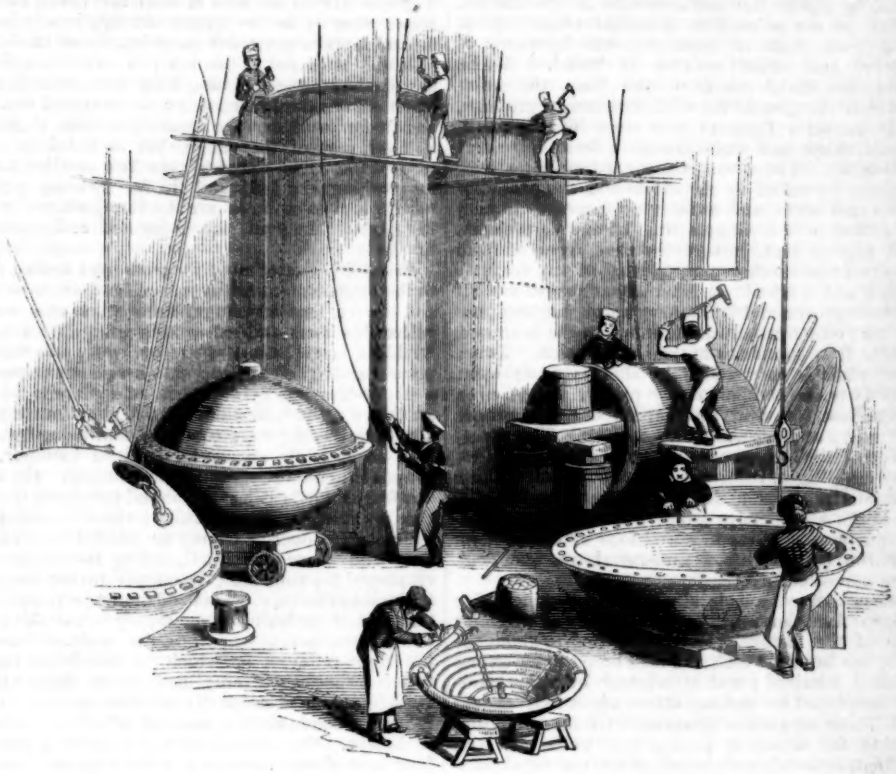
A DAY AT A COPPER AND LEAD FACTORY.



[Coppersmith's Shop.—Messrs. E. and W. Pontifex's Factory.]

AMONG the three or four public thoroughfares leading from Holborn to Fleet Street, is one wherein the "clinking of hammers" may be heard at all hours of the day, and frequently of the night too. The labours of the "Copper-smith" are in no part of London exhibited on a more extensive scale than in Shoe Lane, the thoroughfare here alluded to, in which are many factories for articles of copper, and also of brass, lead, tin, and other metals. To one of these factories, viz., that of Messrs. E. and W. Pontifex and Wood, we shall direct our attention in the present article, those gentlemen having liberally given the requisite permission.

As we have endeavoured in each number of this series of supplements to give a brief outline of some one particular branch of manufacture, in connexion with the establishment visited, we must here make a remark or two on the mode in which many of the manufactures in metal are conducted. All the iron, the copper, the lead, the tin, of which such innumerable articles are manufactured in London, come to the metropolis in a more or less prepared state. The iron, for example, is brought into the state of 'cast-iron' or 'pig-iron' or 'bar-iron' at the iron-works in Wales, Scotland, or the Midland Counties; and is re-cast or re-forged on a smaller scale in London. So likewise the copper, the tin, and the lead are brought into a purified state at the smelting-works in the country, and converted into the various forms at the London establishment. It therefore often happens that the routine of operations necessary for one kind of metal so nearly resembles that required for another, as to lead to the combination of both under one establishment. This is the case at the factory to which our attention will be here directed, and indeed the combination of trades is here so considerable, that a further explanation is necessary. Messrs. Pontifex and Wood undertake the entire arrangements connected with the 'fitting-up' of sugar-refineries, distilleries, and breweries, in all of which copper utensils are used on an extensive scale; and the iron and other metal work required is also finished and adjusted at the establishment. The wooden vessels called 'backs' and 'vats,' used in these three branches of manufacture, are likewise made here, as are also lead-pipes and sheet-lead. The various trades, therefore, of 'copper-smiths,' 'brass-founders,' 'engine-makers,' 'lead-manufacturers,' 'back and vat makers,' and others to be enumerated hereafter, are all combined by this firm.

Under these circumstances, a detailed account of all the operations would be wholly beyond our range in this article: we shall therefore only give a general description of the factory and its internal economy, together with the operations of the copper, lead, and mixed-metal manufacture.

On proceeding from Holborn to Farringdon Market,

through the narrow, crooked thoroughfare of Shoe Lane, we come to an open warehouse, on the outside of which are generally cranes, and porters employed in loading waggons with various manufactured articles of lead or copper. Into this warehouse, which immediately adjoins the northern side of the market, we enter, and see around us a mixed assemblage of rolls of lead, coils of pipe, cog-wheels, parts of machinery, and other articles of metal. Before analyzing the dark, the dirty, the busy, the noisy scene which the ground-floor of the factory presents, we will descend a flight of iron steps leading therefrom, and grope our way through a series of underground vaults. These vaults are used principally as store-rooms for metal in the crude and the partially-manufactured state, and exhibit evidences of a very complete system of arrangement. In one department are the 'pigs of lead,' just as they were received from the smelters; in another are 'blocks' of tin, ready to be melted and worked; in other departments are all the various pieces and parts for pumps, engines, machines, &c., either cast in the foundry on the premises, or brought from foundries in the iron districts. Every room or vault is surrounded by shelves or drawers, every shelf is marked, and every piece of metal, even to the smallest screw or nut, deposited in its proper compartment, and registered in a book. The superintendent of this department, who conducts his operations by lamp-light, receives from the founders these multifarious pieces, and delivers them to the foremen of the works above-stairs when wanted for manufacturing purposes. Many hundred tons of metal, comprising iron, copper, brass, gun-metal, tin, and lead, are here deposited.

In these cellars, too, is situated the opening of a very deep Artesian well, bored a few years ago for the use of the factory. It is excavated to about the depth of one hundred feet, and then bored to the extent of another hundred; and is worked by the steam-engine employed for various other operations above-stairs. Those who are acquainted with the principles governing the action of pumps and wells, are well aware that, probably on account of underground communications through porous strata, the well of one factory is often seriously influenced by the sinking of another several hundred yards distant from it. Such is frequently the case at some of the great breweries; and such is the case at this factory on Saturdays, supposed to be owing to the extensive working, on that day, of the steam-presses for some of the Sunday newspapers in and near Fleet Street.

The factory, being situated on the western bank of the once-famed 'River Fleet,' is twenty feet lower at the eastern than at the western extremity; and such is the loose and porous nature of the soil, once the bank of the stream, that very deep and extensive foundations have had to be made for the furnaces, casting-table, and other heavy machinery on the principal floor. In excavating the ground for forming these foundations, a fact was ascertained, which, as far as we are aware, has never been indicated by any other circumstance—viz., the probable former existence of 'tanneries' at or near this spot: large tan-pits filled with horns were found, having probably been formed on the bank near 'Old Bourne Bridge,' where the 'Old Bourne' (Holborn) flowed into the Fleet. That the water of the latter stream was at one time plentiful and pure enough for the purposes of tanning cannot be doubted. Whether or not the name of 'Shoe Lane' owed its origin to the former location of the leather-manufacture in or near it is a question for the antiquarian topographer to decide.

We now ascend to the main floor of the factory, extending to a depth of a hundred and fifty or two hundred feet from west to east. The northern portion of this range is principally occupied by the mechanism connected with the lead-manufacture; while the southern relates more particularly to the manufacture of copper. On one side we see a large furnace, wherein five or six tons of lead are being melted at once: near it is the square trough into which the melted metal is poured to form large and thick masses of lead. Adjacent to this is a powerful crane for hauling up the lead and passing it on to a system of rollers. Then ensues the apparatus (to be described in a future page) for working the lead into thin sheets. At another part of the range, but included in what is termed the 'lead-foundry,' are two smaller furnaces, for melting the lead and tin for forming pipes and tubes; and in another are the arrangements whereby the pipes, thus cast, are elongated and made ready for use.

From this department we cross over to that devoted to the copper-manufacture; and here such is the din and clatter, that a stranger finds it no easy matter to collect his ideas and see what is going forward. Men wielding large hammers are on every side fashioning vessels and articles of copper: here a sugar-pan, there a sugar-filtering cylinder, in one place a boiler, in another a copper, in a third a still, in a fourth a worm. The metal being very sonorous, and being held on an iron anvil while struck by an iron hammer, yields sounds much more strong than musical. On one side are forges for heating the metal necessary for soldering, or, as it is more generally termed, 'brazing,' such articles of copper as cannot be jointed by rivets; and here and there are small, open, temporary forges, employed for annealing the copper during the progress of the manufacture. Some of the huge vessels seen in this part of the building exemplify in a striking degree the modern improvements in the mode of conducting the sugar-refinery, for which the vessels are intended: this is especially exemplified by the large clarifying cylinders now occasionally used in a certain stage of the sugar-manufacture, some of which are sixteen feet in height. Our frontispiece represents a part of the busy assemblage presented in this 'copper-shop;' most of the vessels seen being connected in some way or other with the sugar-refinery, but others pertaining to distilling or brewing. The lofty cylinders here seen, as well as other parts of the copper apparatus, are for an extensive sugar-refinery, now constructing by the firm at St. Petersburg. This may illustrate one of the peculiar manufacturing features of the present day; where English firms not only fit up our home manufactories, but also undertake the construction and arrangement of factories in almost every country on the globe. In the present case, for example, the firm whose factory we are here describing have undertaken the entire manufacturing arrangements for fitting up a new sugar-refinery in Russia. The plan has been furnished for the guidance of the Russian builders, while the machinery is being made here. There will be ten of these enormous copper cylinders, six 'blow-up' cisterns, also of copper, six copper filtering-vessels of a peculiar construction, vacuum-pans, coolers, cisterns, moulds, and all the varied apparatus for a sugar-refinery. The mechanism and vessels, when completed, will freight a 700-ton ship to St. Petersburg.

In the ground-story are also the 'foundry' and the 'smithery,' which, like the parts just described, require a solid foundation for the heavy furnaces, &c. contained therein. In the 'foundry' are all the arrangements for casting small works in brass, in bell-metal, in gun-metal, and in other mixed metals, where copper, zinc, lead, and tin are the component ingredients. The melting-furnaces, sunk below the level of the ground,

the sand-moulds for casting, and other parts of the arrangements, bear a considerable resemblance to those presented in the bell-foundry noticed in our March 'Supplement.' Here too is an air-furnace, for use in cases where a higher heat is required. The 'smithery' presents the usual assemblage of forges, anvils, and other apparatus necessary for the forging of iron. Nearly all the wrought-iron required in the mechanism fitted up at the factory is forged in this 'smithery.'

Among the mechanical arrangements for facilitating the removal of heavy goods from one part of the factory to another, we noticed an ingenious railway fixed *near the ceiling or roof*, whereby boilers, coppers, stills, engines, &c., suspended from a wheeled carriage or frame, could be easily moved along above the heads of the workmen without disturbing the manufacturing arrangements beneath. This contrivance arose out of the necessity for economizing space, but we are inclined to think that it might be advantageously employed under many other circumstances in large factories.

Let us now pass upwards from the ground-floor, and glance through the upper ranges of shops. The front portion of the first floor is occupied chiefly as a warehouse for finished goods in copper, gun-metal, lead, &c. Here, too, are the various offices and counting-houses, and also a room appropriated to the draughtsmen. In the fitting-up of large factories, such as sugar-refineries and distilleries, there are, as may be supposed, many drawings of plans, sections, elevations, diagrams, &c., necessary not only for making a contract and showing the proposed action of the whole machinery, but as working drawings for the guidance of the workmen. The preparation of such drawings is effected in the office here alluded to, where labelled drawers are devoted to the reception of different classes of drawings.

Behind the ware-rooms and offices extends the 'brazier's shop,' presenting a busy scene of industry. It is a long apartment, having windows all along both sides, and benches immediately beneath them. The 'pattern-room' is another of those which exhibit the advantages of systematic arrangement in a large factory. This room is fitted up with cases, shelves, and boxes, filled with patterns in wood, clay, or metal, of the various pieces required to be cast in the foundry below. Every pattern, large and small, is numbered or ticketed, so as to be readily found when wanted. To let everything "have its place, and be in its place," is the simple but valuable principle on which alone the operations of such establishments as these can be kept free from confusion.

Above the floor just visited is a warehouse for unfinished or partially manufactured goods; and a long shop for the 'back and vat makers.' If we were to speak of 'cisterns and tubs' we should convey a much more definite idea to the minds of general readers, than by using the technical names 'backs and vats;' but the truth is, that each large branch of manufacture has almost a language of its own, the workmen seeming to delight in having a phraseology unintelligible to others. Thus, the brewer's 'liquor-back' is to all intents and purposes a 'water-cistern;' yet not only are the two words 'water' and 'cistern' not used in a brewery, but in some breweries a fine is imposed, and insisted on by the men, on those who may happen to use the plain English words. We make this remark here as the best mode of explaining that a 'back' is the technical name for large wooden cisterns or vessels employed in distilling and similar operations; and that a 'vat' is a tall wooden tub or open cask. The manufacture, which to a small extent is carried on in this range of shops, is a superior kind of cooperage.

The remaining workshops of the factory are occupied by mill-wrights, machine-makers, pump-makers, and others employed in fitting up and putting together the various pieces of metal which, after being cast and forged elsewhere, are employed for the construction of machines and other apparatus. To enumerate all these various machines would be here both impracticable and unnecessary: they are of all degrees of complexity, from a water-cock to a steam-engine, and of various kinds of metal. But we may observe that one of these workshops extends a hundred and fifty feet in length; and along the entire extent of the room, just below the ceiling, and midway between the sides, is a roller or hollow cylinder, kept in rotation by a connecting band from the steam-engine beneath: this, as a source of power, sets in motion a large number of lathes, drilling-machines, screw-cutting machines, &c. placed beneath. In this room all articles of brass, gun-metal, &c., which have been cast in the foundry beneath, are turned, polished, and finished.

The buildings which we have now glanced through are bounded through their whole extent on the south by Farringdon Market, and extend eastward to the rear of the houses in Farringdon Street. So completely is the factory hemmed in by buildings, that nothing can be seen of it externally except from Shoe Lane. That the whole of the stories or floors comprising the building are black and dirty may well be supposed; but it would not be equally correct to suppose that this dirt is valueless. Every morning several persons are employed to sweep all the floors, and to collect the dirt, filings, dross, scraps of metal, &c., into a heap; and this heap is at stated intervals subjected to processes whereby every particle of metal is saved. The dross which arises during the melting of 'pigs' of lead, known as 'lead-ashes,' the clippings, the crust which collects round the melting-pots, and waste pieces of various kinds, whether copper, brass, lead, or tin, are thrown on the floor during the daily operations; and to prevent the loss of the metal contained in this assemblage is an object of some solicitude. In the first place, all the larger pieces of metal are separated; the smaller are passed beneath a rolling-mill; and are then placed in a revolving washing-machine, to be separated as much as possible from the dirt. The pieces of metal which are too fine to be picked out from the heap of dirt by hand, are washed well in water, being held in sieves moved in such a manner as to allow all the dirt to be washed away from the small particles of metal: this is effected by men called in the factory 'dirt-washers,' who have acquired great dexterity in the management of the sieve. Lastly, the regained metal is exposed to the fierce heat of an air-furnace, whereby it is melted into a uniform state; and in this state it is useful for mixing with new copper, to form a compound metal for various purposes. Many tons of valuable metal are thus annually recovered from the otherwise useless dirt of the factory. On several occasions the quantity has amounted to thirty tons per annum, which at seven pence per pound (its estimated value) gives a sum of no mean amount, as the value of the metal regained.

We will now endeavour to follow the routine of some of the processes glanced at in the preceding paragraphs; explaining, as we proceed, the nature of some of the very effective machines brought into requisition. Perhaps it may be well to speak first of the *Lead* manufacture, as it will aid in the subsequent details relating to copper.

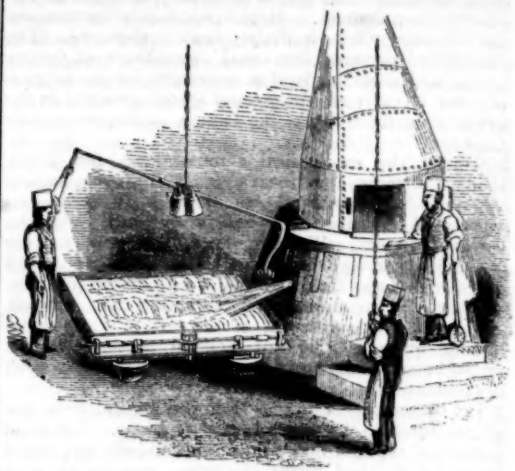
All brass-founders, bell-founders, iron-founders, lead-manufacturers, and similar workers in metal, are desirous of obtaining *old* metal to mix with new. So it is likewise with the glass-manufacturers, who

mix 'cullet,' or broken glass, with the flint and alkali for forming new glass; and also broken crucibles in the manufacture of new ones. The old ingredient gives to the new certain valuable qualities not possessed by the latter when used singly; perhaps because the old material has acquired a better amalgamation, a more complete union of its parts, whether it be a metal, or glass, or baked earthenware. Be this as it may, old lead-pipe, old sheet-lead, old copper-sheathing from ships, old copper-boilers, old bells—all are bought by the respective founders, to be employed in the construction of new articles.

As the amount of old material is, of course, far beneath the quantity required, we have to speak of the form in which the new metal is brought to the factory. In the case of *lead*, the new metal is brought to London in the form of 'pigs,' each of which is an oblong mass, about three feet long, six inches wide, and weighing about one hundredweight and a half. To such of our readers as may be willing to trace the progress of the lead-manufacture from its commencement, we may mention that in Nos. 186, 188, and 303 of the 'Penny Magazine,' are details sufficient to convey an idea of the earlier processes, the mining operations of the present day, the operations of lead-mining in Britain in the time of the Romans, and the smelting of the ore into the form of 'pigs.' From this latter point we now take up the subject. As for the philosophy of the word 'pig,' applied to the masses of lead, we may remark that it forms another curious instance of the phraseology alluded to in a former paragraph. It appears that in the iron-manufacture, when the metal flows from the furnace in which it has been reduced from the ore, it passes into a large trough excavated in sand, and from thence into smaller lateral channels on each side. This arrangement has been suggestive of a sort of simile: for the larger trough is called by the workmen the 'sow,' and the smaller the 'pigs,' who suck the metal from the sow; hence proceeded the names of 'sow-metal' and 'pig-metal,' and hence, in all probability, the name of 'pig,' as applied to the saleable masses both of iron and of lead.

The two principal articles into which lead is manufactured are *sheet-lead* and *water-pipes;* or at least they are the only two which need here be noticed; since the comparatively low temperature at which the metal fuses, and the ease with which it is beaten into various forms, enable the plumber to modify it in various ways. The sheet-lead here spoken of is that with which roofs and terraces are covered and cisterns lined. It is sometimes made, and used formerly to be wholly made, by pouring the melted metal on a flat surface of sand, in a stratum of any required thickness. But the method pursued at Messrs. Pontifex's is the more modern one of rolling, or 'milling,' which we proceed to describe.

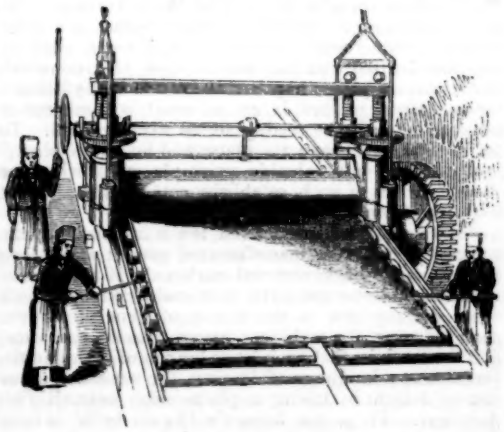
A furnace is provided, consisting of a hemispherical melting-pot, four or five feet in diameter, and nearly as much in depth, heated by a fire beneath, and covered with an enclosed cap or chimney reaching above the roof of the building, for the purpose of conveying away the deleterious gases engendered during the melting of lead. Into this melting-pot is put about six tons (thirteen thousand pounds) of lead, new and old, which remains there till thoroughly melted. During this time all the impurities, being lighter than the metal, rise to the surface. Immediately adjoining the furnace is a cast-iron frame called the 'mould,' being a flat vessel about six or seven feet square and six inches deep. The bottom of this mould is also of iron, and the melted metal is allowed to flow into it from an opened valve near the bottom of the melting-pot. The following cut represents this operation, in which it will be seen that a shoot or trough conveys the metal from the furnace to the



[Lead Foundry.]

mould. The glistening liquid mass soon flows out, to the weight of about ten or eleven thousand pounds, the dross and impurities being for the most part left behind in the melting-pot. As, however, some impurities or oxidised portions enter the mould, a subsequent removal becomes necessary; and this is effected by drawing the edge of a board carefully over the surface of the hot and liquid metal, the board urging before it all the floating impurities, and leaving a surface very silvery and clear.

After some hours the mass of lead, technically called a 'plate,' is lifted out of the mould by a powerful crane, and placed upon the machine where it is to be rolled into the form of sheets. This machine is

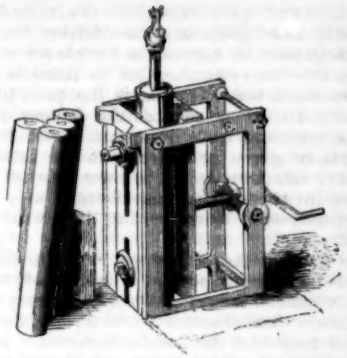


[Lead-Mill and Frame.]

very peculiar in its action. It consists of a long frame or bench, about a yard in height, seven or eight feet wide, and probably seventy feet in length. At intervals of every foot or two are transverse rollers, all placed on the same level, so that a heavy body may be rolled from one end of the frame to the other with great facility. About midway along the frame is the 'milling' or rolling machine, consisting mainly of two ponderous rollers, between which the lead is passed: these

are made of iron, the upper one being 15 or 16 inches in diameter, with a weight of three tons, the under one being the same. By means of very ingenious mechanism, the two rollers are placed at any required distance apart, the one above the other, and are also made to revolve in either direction. These being the mechanical arrangements, the process of 'milling' proceeds thus:—The 'plate' of lead is brought between the rollers, which are opened so as only to receive the lead by compressing it; and the rollers being made to rotate, the plate is drawn in between them. This process is repeated over and over again; the plate passing first from right to left, and then from left to right, the opening between the rollers being gradually reduced by means of an index and graduated dial-plate. The small wooden rollers facilitate the motion of the elongated lead to and fro; and when the length, obtained by reducing the thickness, has become inconveniently great, the piece is cut into two, and each half milled in a similar manner. Thus, the lead continues to pass between the rollers, to the number of seven or eight hundred times, having its thickness diminished and its length increased by regular degrees. From three to four hundred feet in length, with a width of seven or eight, is the average quantity of roofing-lead produced by these means from one of the 'plates.' The lead is then coiled up in a roll, and in that form is sold to the plumber, who adapts it to his various purposes.

The manufacture of lead-pipe, like that of sheet-lead, combines the processes both of casting and elongating or 'drawing.' Whatever be the required diameter and thickness of the pipe, it is first cast in a short piece of great thickness, and then elongated, by which the thickness becomes reduced. The diameter of the cast piece is, internally, the same as that of the required pipe, the external diameter being that which undergoes reduction. The first process is therefore to cast the short pieces of pipe, which is effected in moulds similar to that represented in the subjoined cut. These moulds measure from two to four feet in height, and are fitted for casting pipe whose diameter

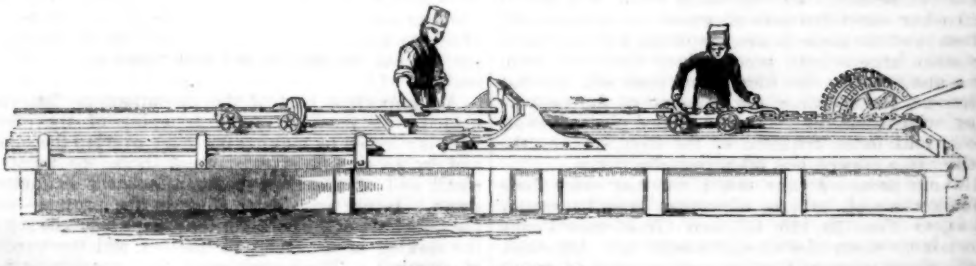


[Mould for casting Lead-pipe.]

varies externally from two to six inches, and internally from half an inch to four inches. The mould consists of two semi-cylindrical halves, which on being brought together form the external contour of the pipe; while a spindle or steel core, running down the centre of the hollow cavity, regulates the internal diameter of the pipe.

A small melting-furnace is appropriated for the pipe-casting, the lead being carefully skimmed from dross while melting; and when the fusion is complete, the melted metal is poured into the mould, the upper end of which is open and the lower end closed. The quantity of lead required for each mould varies from about twenty-four to two hundred pounds, according to the thickness of the pipe. The metal being solidified and sufficiently cool for handling, the two halves of the mould are drawn asunder and the lead removed; the technical name of the 'plug' being applied to the short thick piece of pipe thus produced.

Next ensues the very singular method whereby the 'plug' is elongated to the required dimensions. The 'drawing-bench,' represented in part in the subjoined cut, is a frame about thirty feet long and three in



[Drawing-Bench for Pipes.]

height, having in the middle of its length mechanism for producing the elongation. An endless chain is kept in constant motion round two wheels or rollers, one near the end and the other near the middle of the draw-bench; insomuch that a hook or a clasp connected with one of the links would be forcibly drawn along the bench. A mandril, or steel rod, corresponding in size with the internal diameter of the pipe, is inserted into one of the short pipes or 'plugs,' and then so connected with the endless chain as to be drawn along the bench; but, in its progress, the pipe has to pass through a hole in a steel-plate, or die, rather smaller than the diameter of the lead itself, by which its external diameter becomes somewhat reduced and its length increased. Again and again is the pipe, with its contained mandril, drawn along the frame; the die being exchanged after each drawing and replaced by one of smaller diameter. In producing a two-inch pipe no fewer than sixteen dies are employed, the diameters of which descend in a regular series. The hole through the die is conical, that is, larger on one side of the die than on the other; and the lead enters the hole at the widest part, whereby a process of compression is undergone; but at a certain point in the operations a 'cutting-die' is introduced, that is, one wherein the lead is at once exposed to a cutting-edge, the result of which is, that a thin film is cut or scraped from the whole surface of the pipe. By the time that all this routine is undergone the metal has become more dense and compact, the temperature so high as scarcely to be bearable by the hand, the length greatly increased, and the ex-

ternal diameter proportionably diminished. After this the elongated pipe is removed from the mandril, and is then ready for disposal to the plumber.

Let us now turn our attention to those branches of manufacture in which *copper* is the principal metal employed. So far as regards the factory under our notice, copper is a more important metal than lead; and we have given precedence to the latter simply as a matter of convenience, because many of the early processes in the copper manufacture may be more readily understood by comparing them with those in lead.

When we find that all copper vessels, and indeed almost all the more important articles made of copper alone, are formed from sheet-copper, it may naturally be asked, how these sheets are produced, and whether or not they are made at the London factories. To answer these questions we must point out the difference between the operations of the copper-miner, the copper-smelter, the copper-mill owner, and the copper-smith. The copper-miners, principally at the very western extremity of Cornwall, extract the ore from the metalliferous veins underground, bring it to the surface, and subject it to a slight preparatory process. The copper-smelters then purchase the ore in this state, and take it to the smelting-works, most of which are near Swansea in Wales, and there, by exposure to powerful furnaces, separate the copper from the other metallic and earthy substances with which it was combined. The form into which the copper is brought by the smelters is that of square pieces called 'tiles,' measuring nine or ten inches square and an inch in thickness; and 'cakes,' of a somewhat larger size. These 'tiles' and 'cakes' of copper then pass to the copper-mill, of which there are many in various parts of England, those nearest to the Metropolis being probably those on the river Wandle near Mitcham, Merton, and Wandsworth. Here the copper is remelted, and cast into various convenient forms, afterwards to be passed between rollers, if sheet-copper be required. Whatever may be the particular manufacturing arrangements involved, the mode of casting and of rolling or milling may be sufficiently conceived from the details before given respecting lead. Not only is the copper converted into sheets at the copper-mill, but many of the large pieces, employed for sugar-pans and other large vessels, receive their first rude form there also, certain facilities being possessed for that purpose. Lastly come the labours of the copper-smith, who works up the rudely-shaped pieces into all the various forms required by the sugar-refiner, the distiller, the brewer, and other manufacturers.

Having premised thus much, we may refer those readers who wish to trace the copper from its earlier forms, to Nos. 173, 175, 177, and 179 of the 'Penny Magazine,' where the ores of copper are described, the principal mines of Europe enumerated, the Cornish mining system explained, and the smelting-works of South Wales described.

The vessel called a 'sugar-pan' may be taken as a convenient means of illustrating the operations of the copper-manufacture. One of these is represented in page 165 of our last year's volume, in the description of a sugar-refinery. It consists of a domed vessel, curved and enclosed both at top and bottom, having several apertures for valves, gauges, &c. &c., and a coil of copper-pipe within. The top and bottom, the one convex upwards and the other convex downwards, are each formed of one piece, which receives its curvature by a very remarkable process. The copper is in the first place cast into a form resembling that of a double-convex lens or spectacle-glass, thickest in the middle, and diminishing gradually towards the edges. This lens is then subjected to the powerful blows of a tilt-hammer, directed more continuously near the centre than near the edges. A little consideration will show that this hammering, while it reduces the thickness of the copper, must make it curl up at the edges, or assume a dished or hollow form: we find that this is the case even when a flat piece of metal is hammered at its centre; and still more does this result ensue when an increased substance is given to the centre. The thickness of the centre is so adjusted as to afford metal enough for the curvature of the vessel; and the hammering is continued till the thickness of the whole is brought nearly uniform. This is a very important process, since the fitness of the vessel for the operations of the sugar-refinery depends on the soundness and perfection of the metal. We saw a piece of copper which had been dished or hollowed in this way, and which, though worth forty guineas if sound, was rendered useless by a flaw in the metal.

The curved piece of copper just spoken of receives its form from the tilt-hammers at the copper-mill, and then passes into the hands of the copper-smith for the subsequent operations. The top and the bottom of the 'sugar-pan' receive their form nearly in a similar way; but many smaller pieces have to be added in order to complete the vessel. The side is a portion of a cylinder, made of sheet-copper, and riveted at the edge. One of the most noisy operations in a copper-smith's shop is the hammering which the copper receives in order to render it dense and firm. The piece of copper is supported on an anvil or iron bed, and beaten with hammers in every part, whereby the particles of the metal are brought into more dense and compact union, and an additional degree of toughness is imparted. The ringing and clanging which this produces in a piece of sheet-copper perhaps seven or eight feet in diameter, is to a stranger almost deafening. The name applied to the process is 'planishing;' and where the surface of the copper is very large, the operation has something of the picturesque effect presented by the anchor-smithery; for six or eight men, standing in a circle round the piece of copper, and each wielding a heavy hammer, strike the metal in succession, every part of the surface receiving probably as many as ten or twelve blows. Any one who examines a large copper vessel will see evidences of this 'planishing' process, not only by the hammer-marks, but by the density and 'close-grain' of the surface.

An important part of the operations is that connected with the riveting or fastening of the joints. This is effected by making one edge overlap the other, and by passing a rivet through them, the point or small end of the rivet being afterwards hammered down. Hence arise three steps in the process—viz., the punching of the holes for the reception of the rivets, the making of the rivets themselves, and the process of riveting. The punching-engine consists principally of a long lever, to the shorter arm of which is attached a punch corresponding to the size of the hole to be made, and generally of a cylindrical shape. The piece of copper is brought to the engine, and placed between the punch and the support beneath, so adjusted as to cause the punch to act on the exact spot where the hole is to be made. A pressure of the lever now causes the punch to descend on the copper, and to cut out a small circular piece corresponding with the required size of the hole. The piece of copper is then shifted onward through a small space, and another hole similarly made; and so on to the required extent.

In the process of riveting, each rivet, which is made at the forge, is passed into the hole bored for its reception, and the point or small end of the rivet is hammered down close to the sheet-copper, so as to clasp it very

tightly, having in fact a head or stay within and without. The edge of the copper is then 'caulked,' that is, hammered so as to bring the two surfaces of the joint into very close contact, forming a bond so intimate as to resist the passage of water, air, or steam.

Several of the openings into a sugar-pan, or indeed into other copper vessels used in manufactures, are not simply holes cut in the sheet-metal, but have collars or edges made of cast-metal, whereby the fastening can be effectually secured. These various pieces—the technical names for which need hardly be given here—are cast in sand in the usual manner, and are afterwards turned and finished by other means.

The coil of steam-pipe which occupies the lower part of the interior of a sugar-pan, as a means of heating the sugar to be contained therein, involves operations of a different kind from those hitherto described. This coil usually consists of pipe about three inches in diameter, but much thinner than the same diameter of lead-pipe would be. In order to form it a strip of copper is taken, as long as may be conveniently obtained, and rather wider than the circumference of the intended pipe. The two edges of this strip are bent upwards, to give the first semblance of a curve; and the piece is then passed through the holes or 'dies' of the tube-drawing machine, by which it is made perfectly cylindrical, with one edge slightly lapping over the other. The joint thus made is secured by a process of soldering or brazing, aided by heat in the usual manner. Soldering or brazing, it may perhaps hardly be necessary to state, depends for its action on the different temperatures at which different metals melt. Thus, to join two pieces of lead, a mixed metal, or 'solder,' is employed which melts and acts as a cement at a temperature that will not injure the lead. So, in like manner, two pieces of copper are joined or 'brazed' by using a mixed metal partaking of the nature of brass, which remains fluid at a temperature not high enough to injure the copper. A small forge or brazing-furnace is employed to heat the metals, and borax is employed to facilitate the fusion of the brass.

Thus far the operations for making a copper-pipe are apparently simple; but the mode of bringing the straight pipe into the form of a coil is very curious. Any attempt to bend a pipe in this manner, so long as the metal is thin and the pipe empty, would be accompanied by a distortion of the sectional area of the pipe, originally circular, and perhaps by fracture. To obviate this, therefore, the interior cavity of the pipe is entirely filled up, either with lead, or with some composition which will melt and flow at a temperature not likely to injure copper. This being effected, the pipe becomes solid, and may then be bent without disturbing its shape, by the application of sufficient power. By a simple machine, downward pressure is exerted on the pipe at one part, while upward pressure is exerted on the adjoining parts, whereby the pipe is gradually coiled round into a form nearly resembling that of a common tea-saucer, fitted to lie in the bottom of the sugar-pan. By the application of heat on a temporary stove beneath, the interior composition is melted out, and the vacancy restored. The strength of the tube is tested by exposure to steam of high pressure for several days; various minor adjustments are effected; and the coil is inserted in the sugar-pan.

Nearly all the vessels manufactured by the coppersmith are produced by various modifications of the processes here noticed. Cutting, hammering, riveting, planishing, brazing—these are the principal operations performed. If we were to select any other article, and trace it through the successive processes, we should find it, so far as mere description goes, little else than a repetition of the above details. There are, however, some exceptions to this statement, which we may here notice.

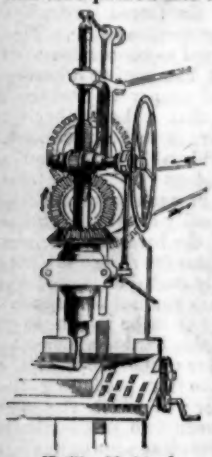
In the process of hammering the plates or large surfaces of copper, the hammered surface becomes hardened; and to remedy this, the copper is exposed to a strong heat for a certain time, and then plunged into water, by which an oxide is removed and the copper softened. For large sheets, this process of annealing is effected on a flat stove about three feet from the ground; the stove being covered with burning fuel, and the copper laid thereon. A cistern of water is kept beneath the floor of the shop, near the stove, into which the heated copper is suddenly plunged, as a means of removing the external oxide. For smaller pieces temporary stoves or fires are adjusted in any convenient part of the shop, a draught being ingeniously supplied by a current of air forced through a flexible tube by the action of the steam-engine. This process of annealing is not effected in connection with the 'planishing,' but with that hammering whereby the shape of a curved piece of copper is produced. Let us suppose, for instance, that a hemispherical copper cup, a foot in diameter, is to be produced. A circular piece of copper, considerably more than a foot in diameter, is selected, laid on a sort of small convex anvil; and hammered in such a manner as to make the upper surface gradually convex. This is effected by a peculiar action of the hammer, whereby the metal is as it were driven from the centre towards the circumference, and gradually curled or turned up. But it happens that after a certain amount of hammering, the copper becomes so hard as to be in danger of fracture; and it is to remove this hardness that the 'annealing' is effected. In one of the shops of the factory is an ingenious machine for producing the curvature of a piece of copper; in which the copper is worked to and fro between two small wheels or rollers, placed in more or less close approximation according to the pressure required.

The manufacture of copper-plates for engravers, one of the departments carried on at the factory of Messrs. Pontifex, will illustrate the means adopted for producing a level and brilliant polished surface of copper. The copper is in the first instance cut to the required size from a plate of the best and soundest quality; and is then scraped all over with a steel instrument to remove any slight defects that may exist at the surface.. The workman occasionally holds a piece of oiled paper between the window and the plate, whereby a peculiar light falls on the latter, calculated to render the minutest flaws or defects visible. When scraped sufficiently, the plate is taken to an anvil and well hammered, to render it more dense, and also to flatten it. The surface is then well ground with a kind of hard blue stone wetted with water; and finally polished with fine charcoal, by which all the marks from the scraping, hammering, and grinding are removed. When it is considered that the finest lines produced by the graver must be made perfectly distinct and clearly marked, it may well be supposed that the surface is required to be free from scratches and imperfections of every kind.

Of the sugar-moulds, the clarifying-vessels, the stills and other vessels employed by distillers, the coppers for brewers, the copper baths, the copper boilers, and other vessels made of this metal, we shall refrain from saying more here. All are made of sheet-copper, all are hammered and annealed, and all are either riveted more or less extensively, or brazed. Let us then say a few words in reference to other operations of the factory.

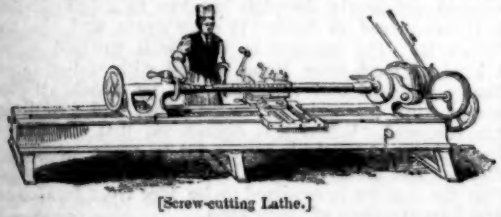
There are, in various branches of manufacture,

many small pieces of mechanism made of brass or of some of the numerous compound metals in which copper is an ingredient, and which are usually cast in a melted state before final adjustment. For the production of such articles one department of this factory is appropriated. Pumps, water-cocks, valves, weights, measures, tubes or short pipes—these and scores of other articles are cast in loam or sand in a manner analogous to that of bell-founding. The model or pattern is made of different substances, according to the form of the instrument; and in those instances where an interior cavity is to be formed, there is an inner mould or model adapted to it. The metal, whether brass, or pot-metal, or bell-metal, or gun-metal, is melted in pots made of Stourbridge clay, by means of pot-furnaces placed beneath the level of the ground, and then poured into the cavities of the sand-mould.



[Drilling-Machine.]

All such articles, when cast, have to undergo many processes before they are fitted for use; and to this object some of the upper shops of the factory are devoted. The internal cavity of various pieces of mechanism has often to be brought to great regularity and smoothness; this is effected at a lathe by means of steel instruments. An internal or an external screw or worm has sometimes to be formed; and this is likewise effected at the lathe, of which there are as many as sixty in one shop, some of a very elaborate and beautiful kind. Sometimes holes are to be drilled, more carefully and regularly than can be effected by the copper-drilling machine in the lower shop; and in such case the elaborate machine here represented is employed. Then again parts which work into or upon each other require various adjustments to make them work smoothly and regularly; and the outer surfaces of all are to be polished and beautified. All these operations, and many others which we cannot enumerate, constitute a bustling scene of industry in the upper shops of the factory; the lathe, the file, and various polishing-tools being the chief implements employed. Of the lathes here alluded to, one is the beautiful machine for cutting screws, represented in the subjoined cut: its mechanism is at the same time



[Screw-cutting Lathe.]

so extensive and so delicate, that it will cut a screw whose threads are eight inches apart, or one which has a hundred threads to the inch, or one having any intermediate number between these wide extremes. The principle of the machine rests on the combination of two movements—a rotatory motion of the bar to be cut into a screw, and a longitudinal motion of the cutting tool; and the distance between the thread of the screw depends on the ratio between the velocities of these two movements.

We stated, in the commencement of this article, that our description of processes must be confined to two or three branches, being those forming the chief features of this establishment. To show how impossible it would be to go beyond these limits, we will here simply enumerate the distinct branches of manufacture carried on, comprising works in five or six different kinds of metal. 'Copper-smiths,' for making coppers, boilers, baths, stills, sugar-pans, sugar-clarifying and filtering vessels, coolers, fire-boxes for locomotive engines, &c.; 'copper and steel engraving-plate makers,' whose avocations are implied in the name; 'brass-plate makers,' in relation to the brass-plates for inscriptions; 'fire-engine makers;' 'beer-engine makers;' 'pump-makers;' and, in short, makers of numerous engines and machines, wherein various kinds of metal are employed; 'millwrights,' for making the shafts, wheels, cranks, &c. whereby a moving-power is applied to manufactures (nearly all the machinery contained and worked within the factory is manufactured there also); 'brass, copper, and gun-metal founders,' for innumerable articles made of those metals; 'brass-turners;' 'gas-meter makers;' 'lead-pipe and sheet-lead manufacturers;' 'pewterers,' for making certain parts of the apparatus used in some distilling and chemical processes; 'back and vat makers,' for making the mash-tuns, hop-backs, under-backs, coolers, stillions, store-vats, and other vessels of wood used in breweries and distilleries; and other branches of a minor character. We do not remember to have seen any other factory wherein so many departments of manufacture are carried on at once, although many of these are necessarily here conducted on a small scale.

We have in general made a point of avoiding all allusions to the private economy of manufactories, farther than regards the processes carried on therein; but there is one point on which we will here offer a few remarks. It must be obvious that where some hundreds of men are employed, some working by the day and others by 'piece-work,' and where scores of different materials are used, the commercial accounts of a factory must require extreme care, and a well-organized system, to prevent the most inextricable confusion. A merchant who imports foreign produce to sell again at a profit, has comparatively an easy task in booking his transactions; but the manufacturer who makes an engine, consisting of many scores or even hundreds of parts, some of one metal and some of another, and made by men of whom some are paid by the day and others by the piece, has a task of no mean difficulty in estimating the actual cost of a machine. We have had an opportunity of observing the system pursued in the factory to which these pages relate, and have been much struck with the elaborate, but yet simple, principle of checking all the accounts. Every piece of copper, of brass, &c. is weighed when given by the store-keeper to the foreman of the works; every order has a symbol attached to it, not only on the books, but also stamped on the principal pieces of metal employed; the mode in which every hour of every man's time has been employed is strictly ascertained, in connexion with the symbols attached to the respective orders; the 'time' of each workman is so ascertained and recorded that an error can hardly occur; and the wages and materials are so classed as to afford ready means of reference at any subsequent time. The details of the system we of course cannot enter into; but we may remark, that a period of six or eight years is stated to have elapsed in bringing the system, by gradual stages, to the degree of completeness necessary for the complicated operations of the factory.